

# Advancing Systems Engineering Practice using Model Based Systems Development (MBSD)

## Systems & Software Technology Conference

26-29 April, 2010



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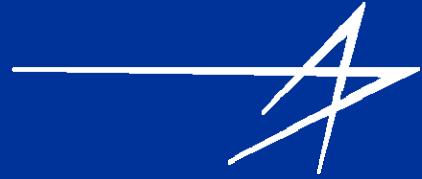
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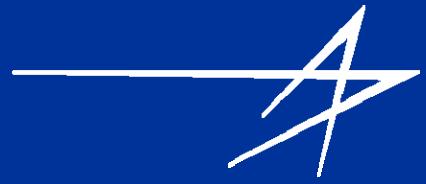
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# Topics



- **Model-based Systems Development (MBSD)  
Motivation and Scope**
- **System Modeling Using SysML**
- **System Model as an Integration Framework**
- **Deploying MBSD into your Organization**
- **Summary**

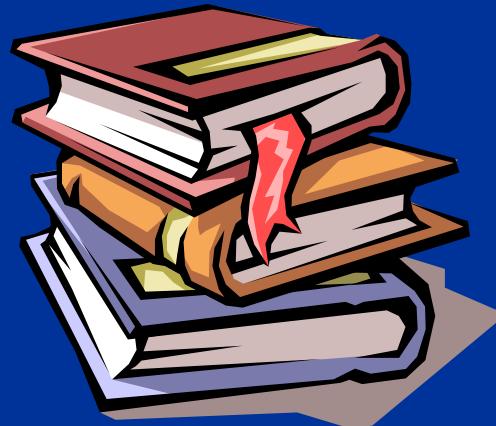


# MBSD Motivation and Scope



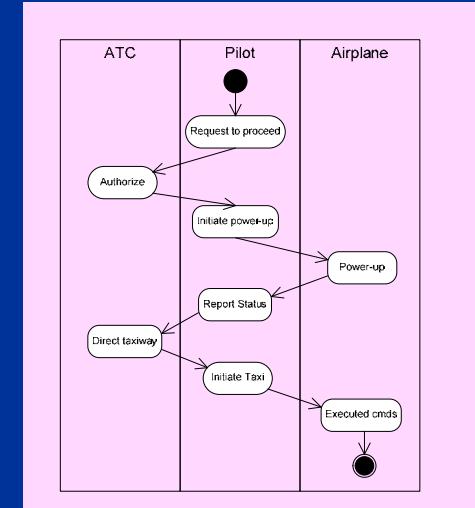
# Practices for Describing Systems

*Past*



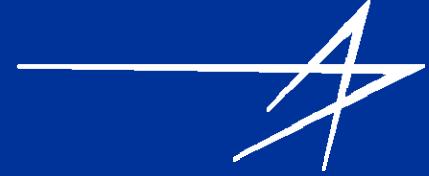
- Specifications
- Interface requirements
- System design
- Analysis & Trade-off
- Test plans

*Future*

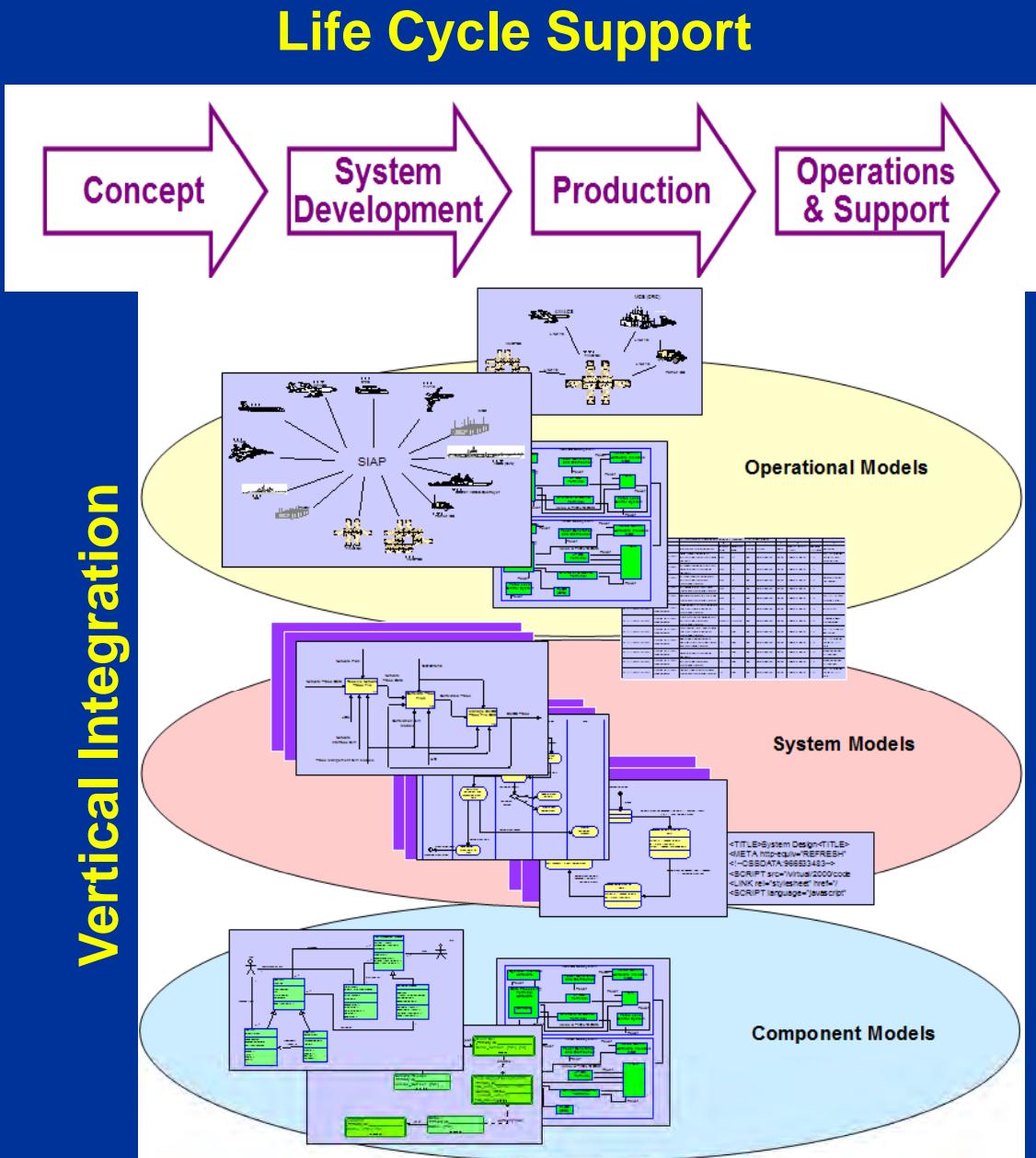


Moving from Document centric to Model centric

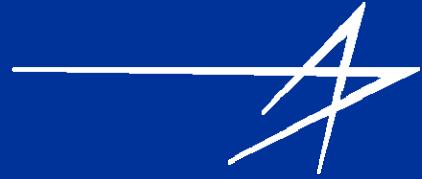
# Model-based Systems Development (MBSD)



- **Formalizes the practice of systems development through use of models**
- **Broad in scope**
  - Integrates with multiple modeling domains across life cycle from system of systems to component
- **Results in quality/productivity improvements & lower risk**
  - Rigor and precision
  - Communications among system/project stakeholders
  - Management of complexity

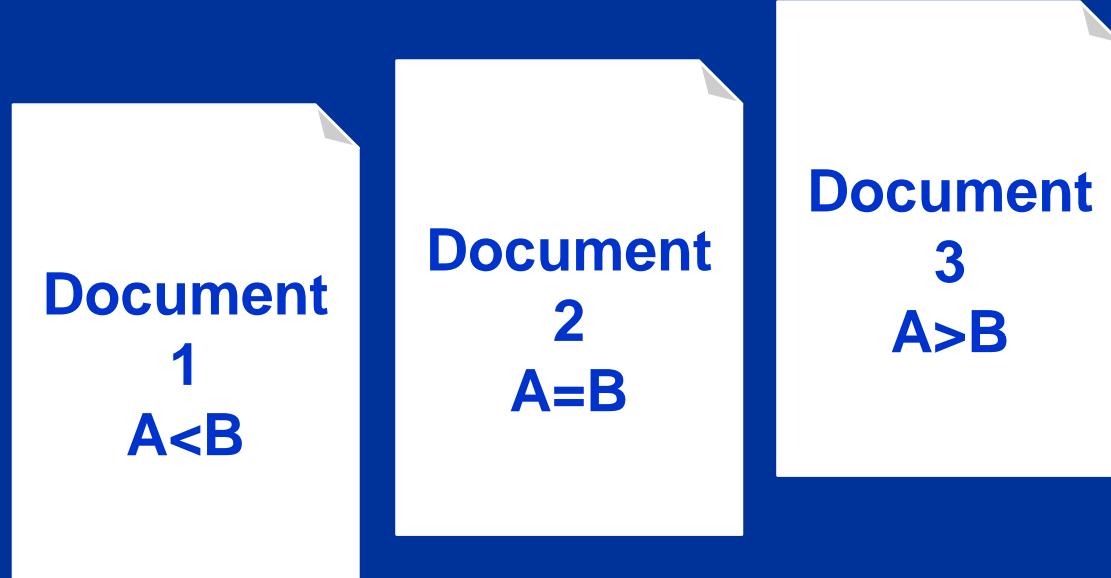


# System Description



- *Document-Based System Engineering:*

Where is  
truth?

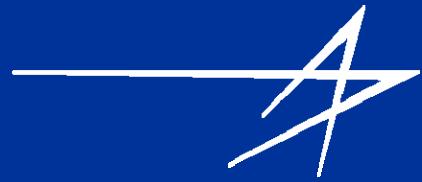


Inconsistencies within and among documents

- *Model-Based System Engineering:*

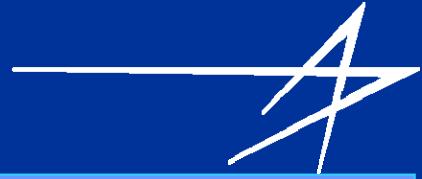


Model enforces consistency



# System Modeling Using SysML

# System Modeling

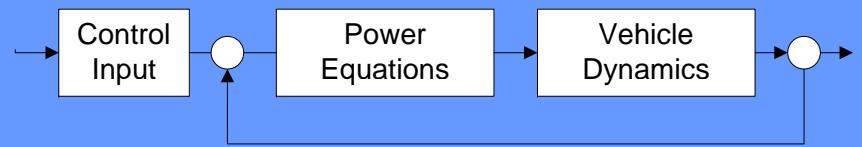


Requirements

Functional/Behavioral Model



Performance Model

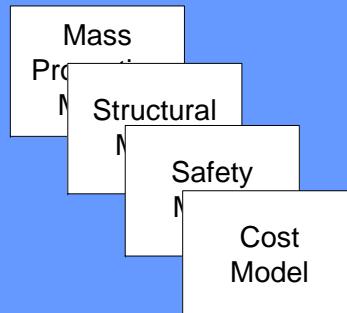


System Model

Structural/Component Model

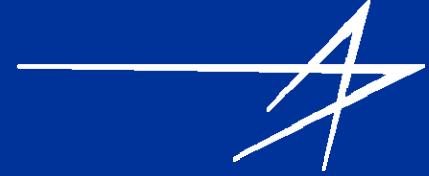


Other Engineering  
Analysis Models



**Integrated System Model Must Address  
Multiple Aspects of a System**

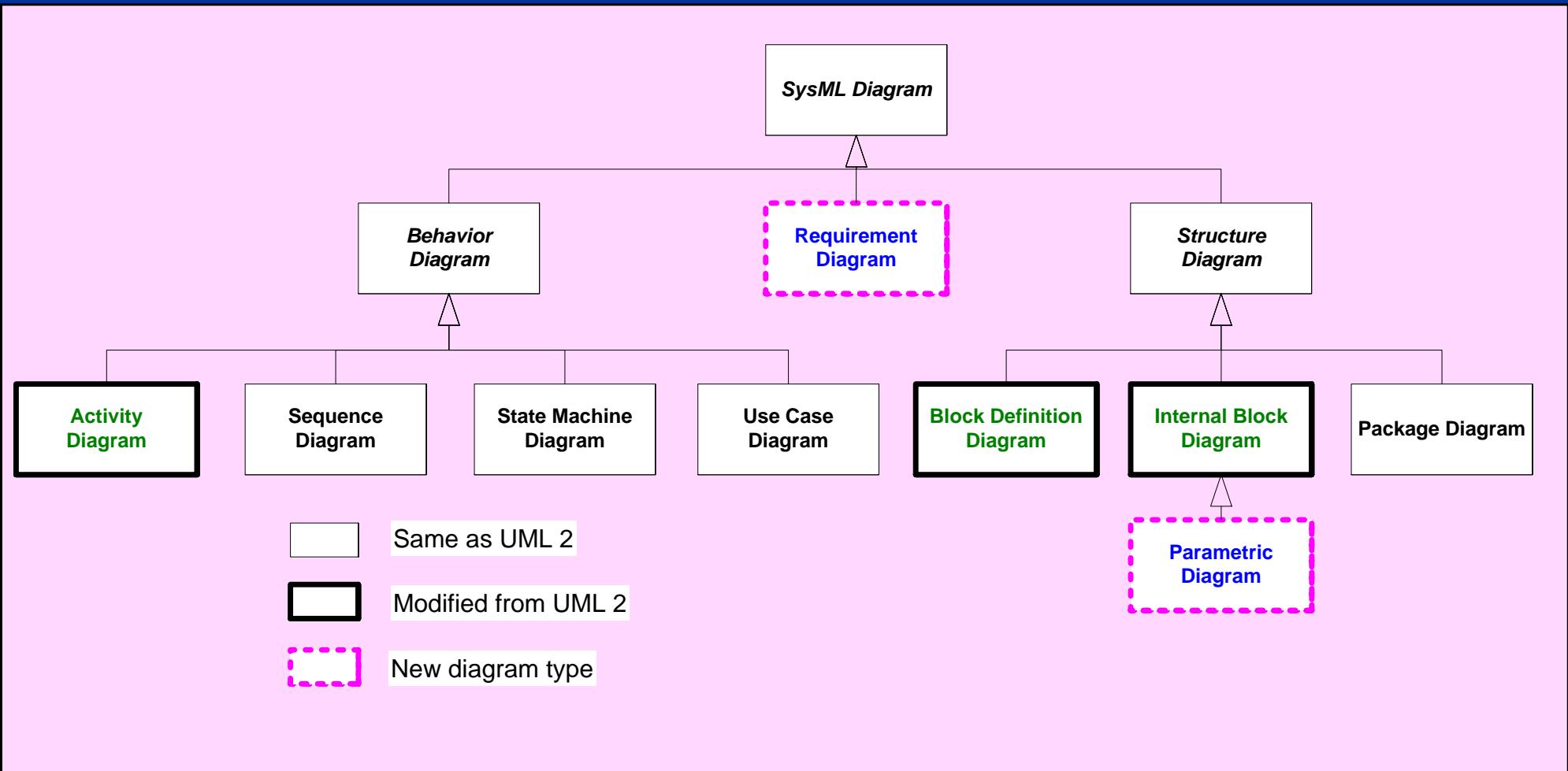
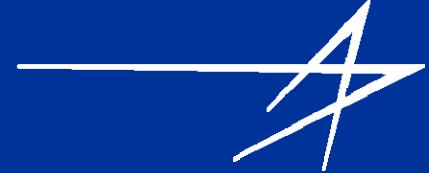
# What is SysML?



- **A graphical modeling language in response to the UML for Systems Engineering RFP developed by the OMG, INCOSE, and AP233**
  - a UML Profile that represents a subset of UML 2 with extensions
- **Supports the specification, analysis, design, verification, and validation of systems that include hardware, software, data, personnel, procedures, and facilities**
- **Supports model and data interchange via XML Metadata Interchange (XMI®) and the evolving AP233 standard (in-process)**

**SysML is Critical Enabler for MBSE**

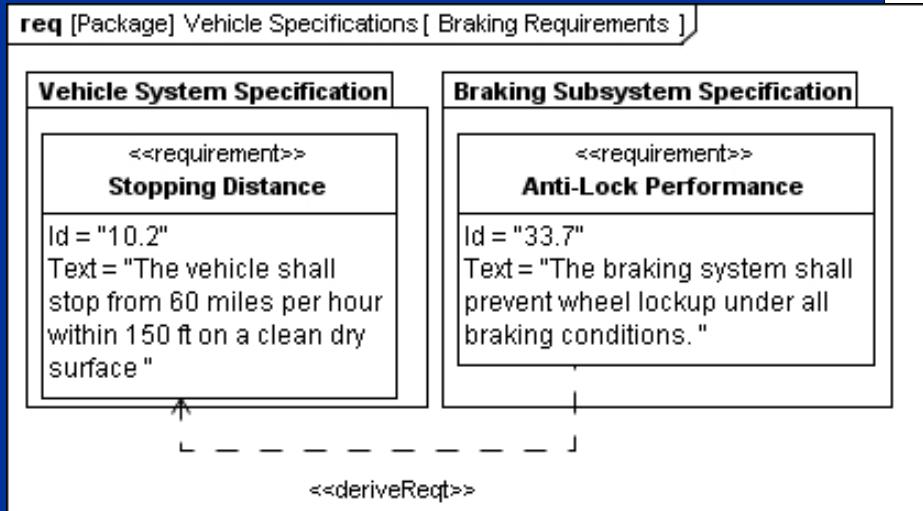
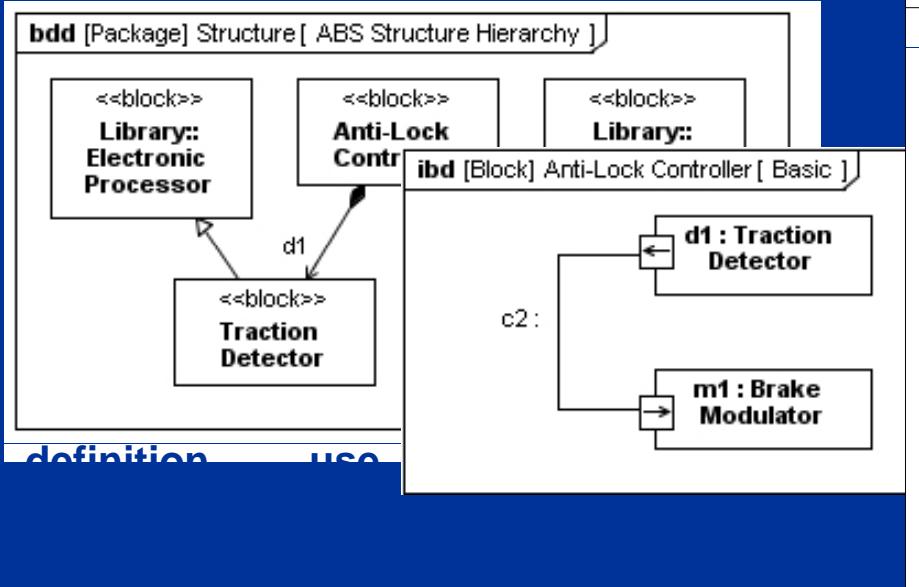
# SysML Diagram Taxonomy



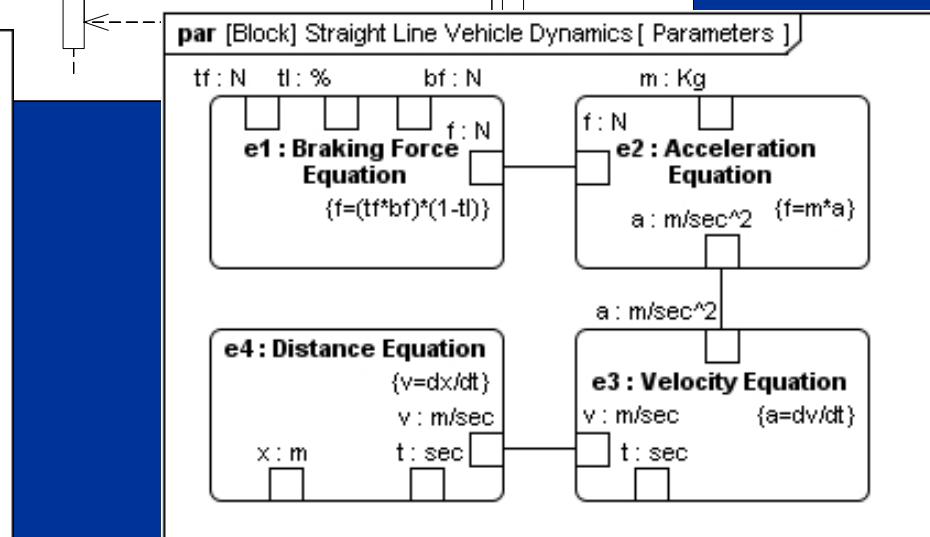
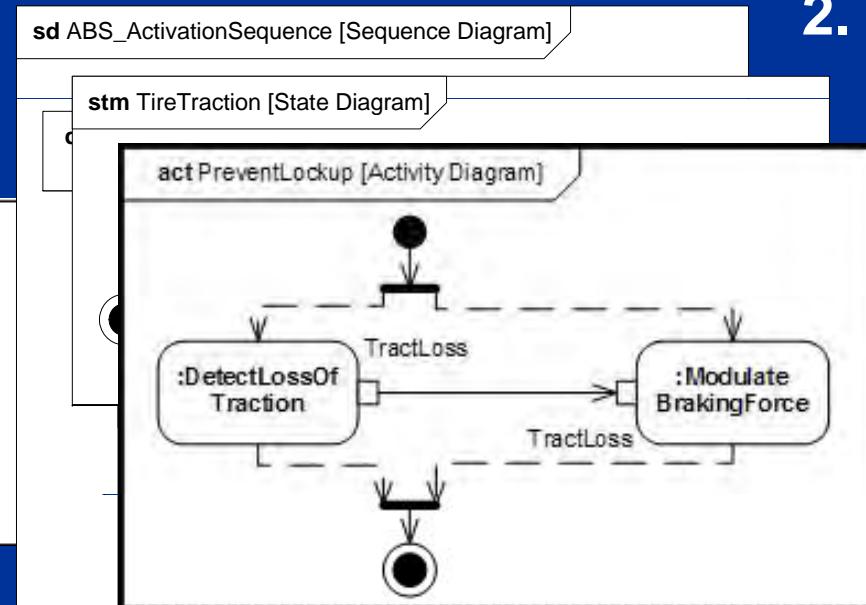
# 4 Pillars of SysML – ABS Example



## 1. Structure



## 2. Behavior



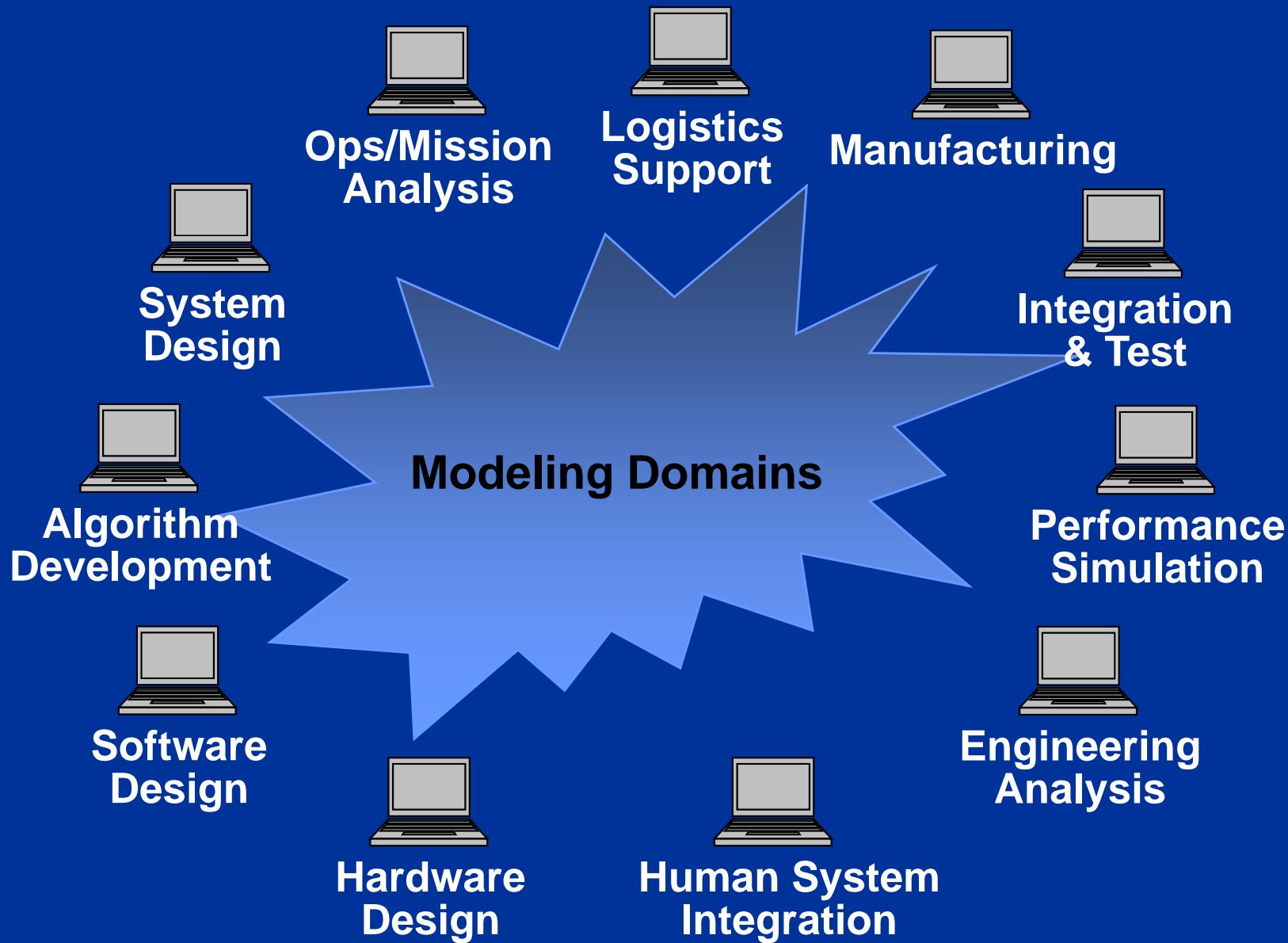
## 3. Requirements

## 4. Parametrics

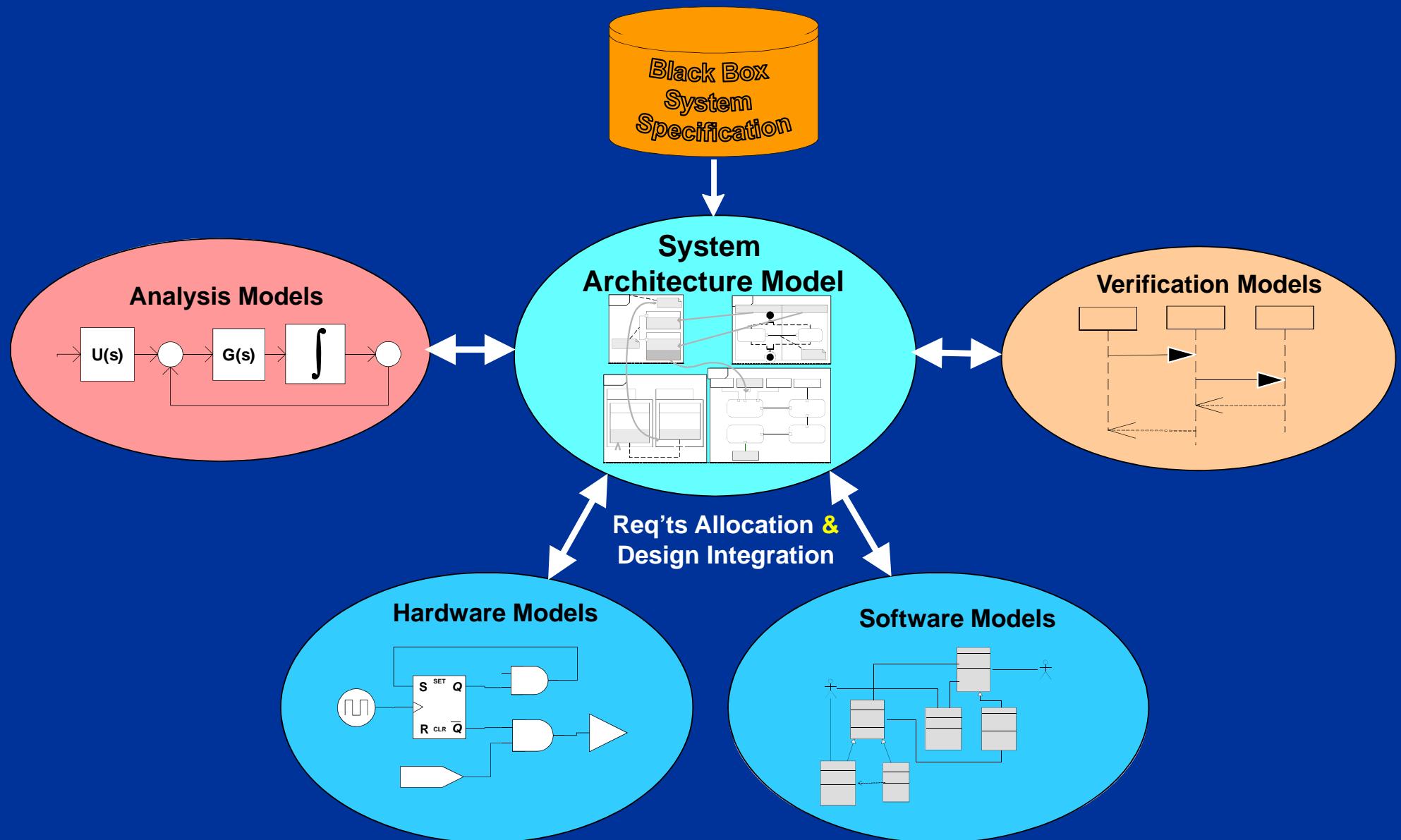


# System Model as an Integration Framework

# MBSD Must Integrate across Modeling Domains



# Using System Architecture Model as an Integration Framework



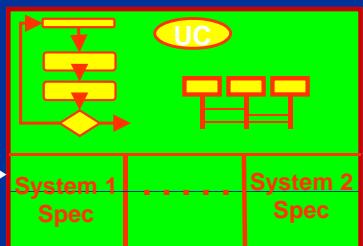
# Using the System Architecture Model to Flowdown Requirements

## System-of-System Level

- 1st Level Of Decompositions
- How Our System Contributes to the Overall Mission



Mission Concept of Operations



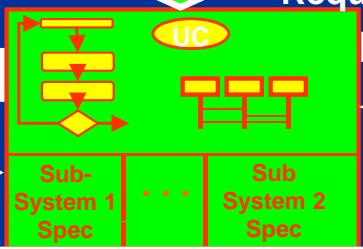
Trade Studies, Simulation, Specification Reviews, etc.

## System Level

- Derives Subsystems
- Allocates Requirements to Subsystems



A-Spec



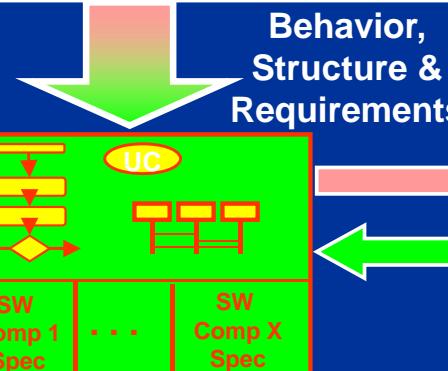
Trade Studies, Simulation, Specification Reviews, etc.

## Element Level

- Derives Hardware and Software Components
- Allocates Requirements to Components



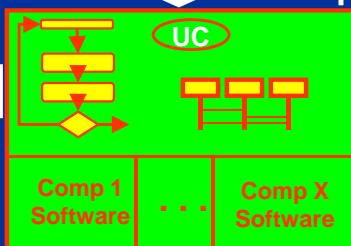
B-Spec



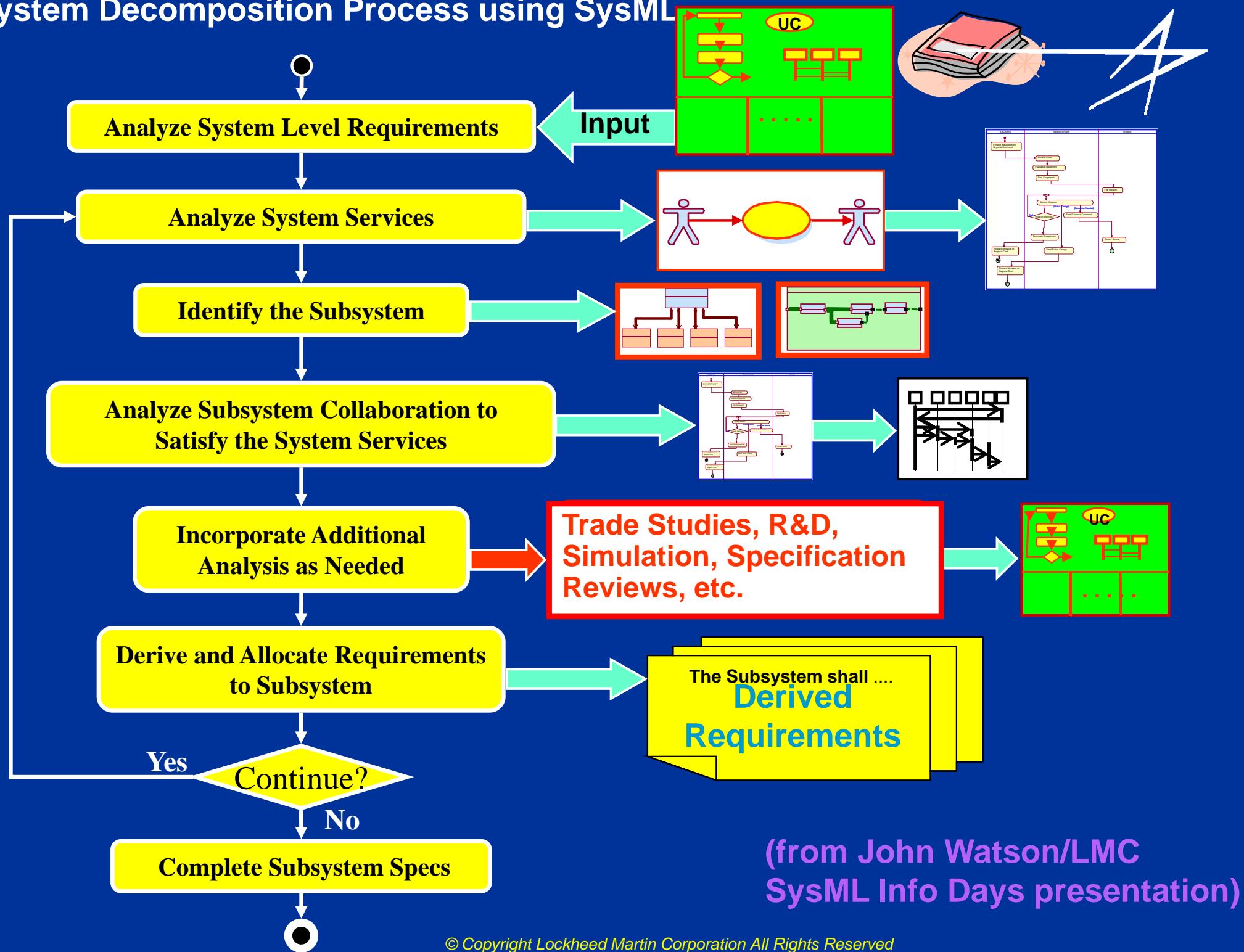
Trade Studies, Simulation, Specification Reviews, etc.

## Component Design & Implementation Level

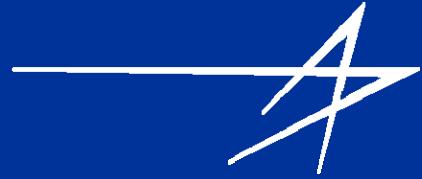
(from John Watson/LMC SysML Info Days presentation)



# System Decomposition Process using SysML

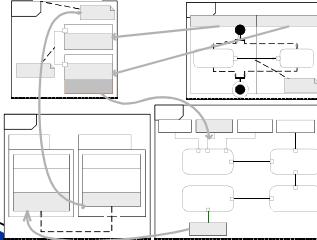


# System Architecture Model to Support Tradeoff Analysis



Analysis  
Results

System Architecture Model

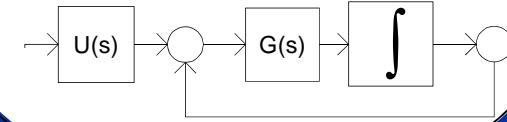


Alt 2 Alt 3

Subsystem	Alternative1	Alternative2	Alternative3
Sensor	Sensor1	Sensor2	Sensor3
Processor	Processor1	Processor2	Processor3
Control	Control1	Control2	Control3

Cost  
Reliability

Performance



Criteria	Weight	Alt 1	Alt 2	Alt 3
Performance	0.5	7	5	5
Reliability	0.2	4	6	5
Cost	0.3	3	5	8
Effectiveness		5.2	4.2	5.9

par Overall Effectiveness

Optimization

$$\{E = \text{Sum } [w1*u1(P) + w2*u2(R) + w3*u3(C)]\}$$

Effectiveness

E :Objective Function

P R C

Performance

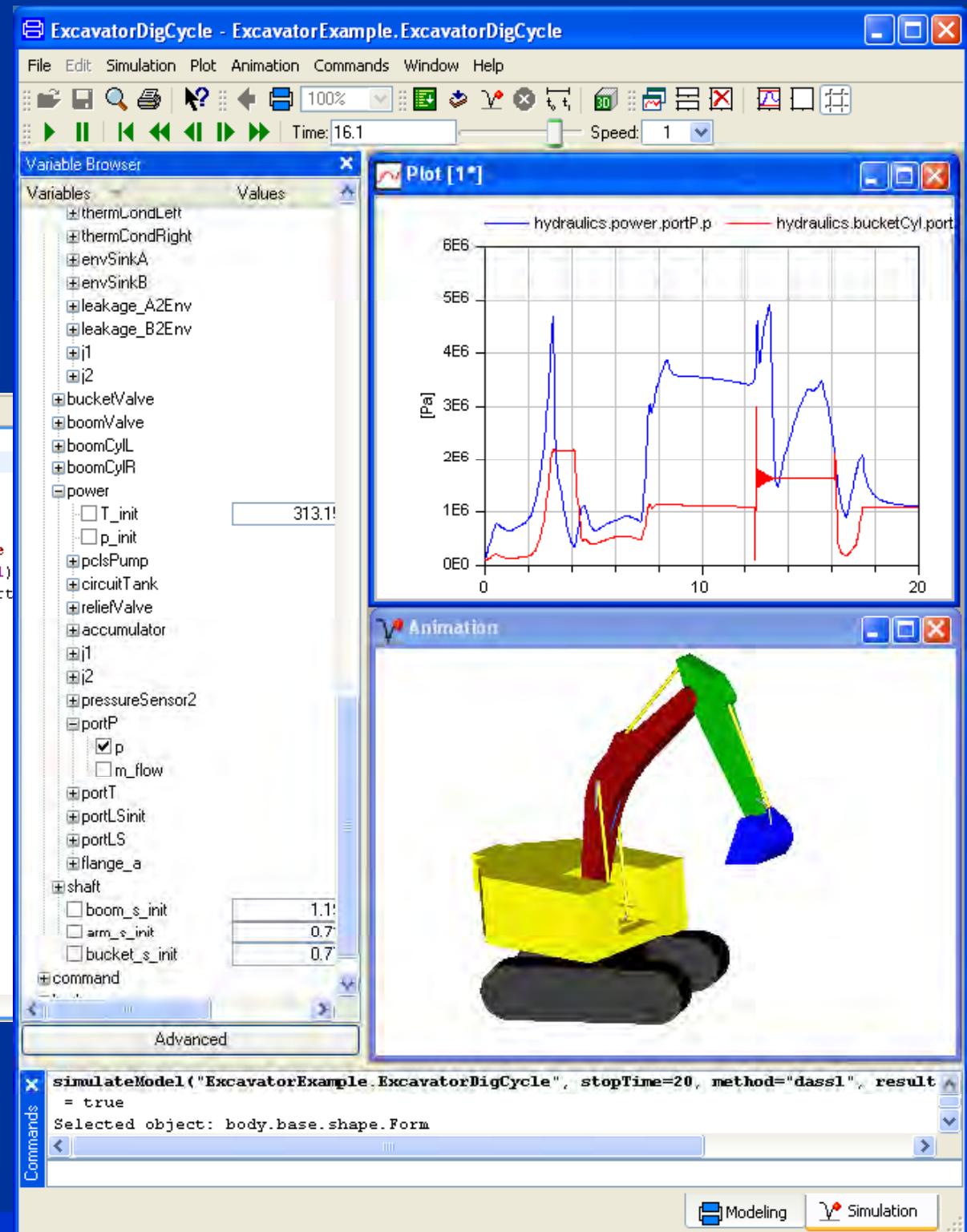
Reliability

Cost

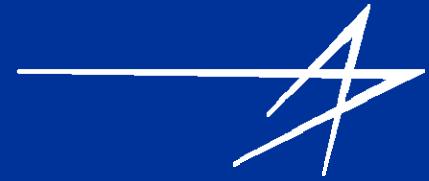
# Integrating SysML with Simulation GIT\* Project

Modelica  
Lexical Representation  
(auto-generated from SysML)

```
*ExcavatorExample.mo x
package ExcavatorExample
...
class ExcavatorDigCycle
    Modelica.Mechanics.MultiBody.World world;
    ExcavatorExample.Components.Hydraulics hydraulics(redeclare
    ExcavatorModel.SubSystems.DigCycleSeq command(startTime=0.1)
    ExcavatorModel.SubSystems.MechanicsBody body(swing_phi_start
    ExcavatorExample.Interfaces.Nodes.TransNode2 node;
equation
    connect (hydraulics.boomCylBaseL, body.cylBoomLeftBase);
    connect (hydraulics.boomCylRodR, body.cylBoomRightRod);
    connect (hydraulics.boomCylRodL, body.cylBoomLeftRod);
    connect (hydraulics.armCylRod, body.cylArmRod);
    connect (hydraulics.armCylBase, body.cylArmBase);
    connect (hydraulics.bucketCylRod, body.cylBucketRod);
    connect (hydraulics.bucketCylBase, body.cylBucketBase);
    connect (hydraulics.commandSignal, command.commandSignal);
    connect (world.frame_b, body.baseFrame);
    connect (hydraulics.swingFlange, body.swingFlange);
    connect (hydraulics.boomCylBaseR, node.a);
    connect (node.b, body.cylBoomRightBase);
end ExcavatorDigCycle;
end ExcavatorExample;
```

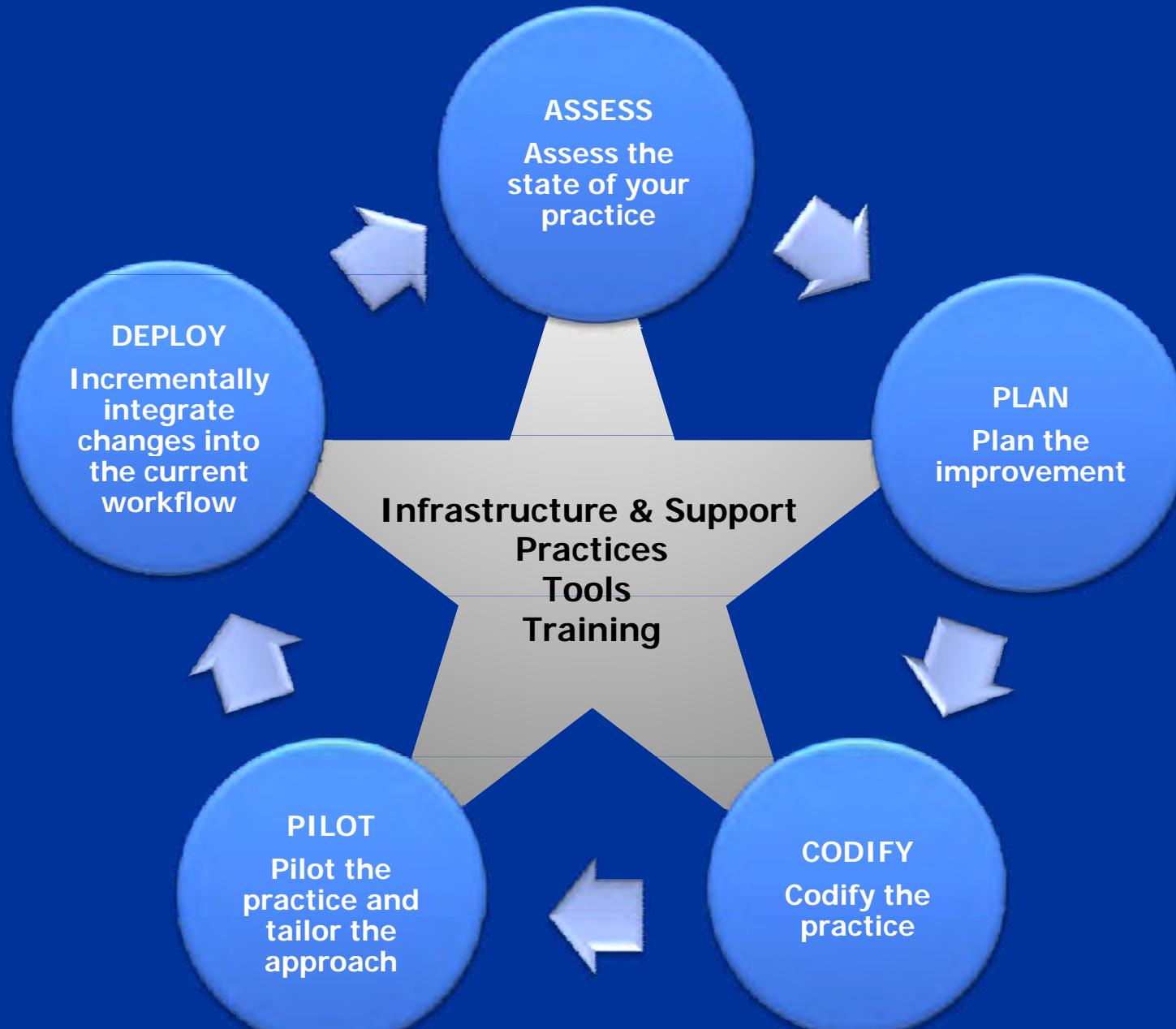
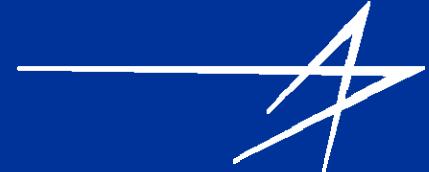


[Johnson, 2008 - Masters Thesis]

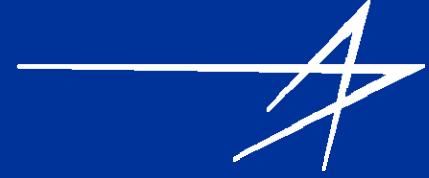


# Deploying MBSD into Your Organization

# Deploying MBSD as part of Improvement Process

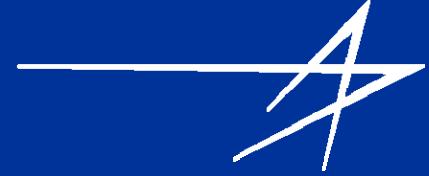


# MBSD Observations



- Transition from document-centric to model-centric is a cultural change
- Well defined MBSE method is essential
- Multiple tool vendors provide a range of price point, capability, and standards conformance
- MBSE training should include language, method, and tools
- Employ pilots to validate your MBSE approach
- Need buy-in from program and customer on MBSE benefits, approach and deliverables
- Scope model to support program objectives and within program constraints
- *A lot has been learned, but much more remains*

# Summary



- **MBSD is a key practice to advance complex systems development**
- **Standards such as SysML and UML are critical enablers of MBSD**
- **Multiple tool vendors implementing SysML**
- **System architecture model and standards based approach facilitate integration across modeling domains**
- **Growing interest and application of MBSD**

# Acronyms

- **MBSD** – Model-based Systems Development
- **MBSE** – Model-based Systems Engineering
- **OMG** – Object Management Group
- **SysML** – Systems Modeling Language
- **UML** – Unified Modeling Language